BULL. BOT. SURV. INDIA
Vol. 11, Nos. 3 & 4 : pp. 330-334, 1969

SAPONIN DISTRIBUTION IN ANGIOSPERMS AND ITS BEARING ON THEIR CLASSIFICATION

B. C. KUNDU
Bose Institute, Calcutta
AND
B. GUPTA
Central Drug Research Institute, Lucknow

ABSTRACT

In this paper the groups of plants in which saponins are reported to occur have been listed, and their relationships shown according to the phylogenetic system of classification of Hutchinson. Steroidal saponins mostly occur in different orders of the division Corolliferae of subphyllum Monocotyledons; they are also present in a few families of Dicotyledons like Solanaceae, Scrophulariaceae, Acanthaceae, etc., but saponins present in these families are somewhat different in their nature. Triterpenoid saponins are mostly distributed in some orders of the division Lignosae of the subphyllum Dicotyledons. In this division, Euphorbiales and related orders, Capparidales and related orders and Rosales and related orders are important sources. In the division Herbaceae some orders like Caryophyllales and Berberidales are also important sources of triterpenoid saponins. There is a marked affinity among plants containing similar saponins. Hutchinson's classification comes very close to the arrangement based on saponin-content. Some suggestions for modification of the classification in the light of saponin-content has been made. A plea is made that phylogenetic system of classification should take into account the presence of saponins and other chemical constituents.

Botanists as well as chemists have been for many years trying to find out taxonomic relationship between different plants or groups of plants containing similar chemical constituents. The occurrence of alkaloids and glycosides of similar structures in different genera of plants of the same family has been noticed repeatedly. Such findings would indicate similar mechanisms of biosynthesis and analogous metabolic features. (*Chatterjee*, 1958). Henry (1949) has reviewed this problem in a general manner. Manske and Holms (1950) considered this in relation to the whole phylogenetic system of Angiosperms. Hegnauer (1963) has also discussed those aspects of alkaloids that are of direct interest to plant taxonomy. Bate-Smith (1959) and Gibbs (1945, 1954, 1960) observed that closely related plants contain similar constituents and can often act as a guide to the nature of an unknown isolated compounds. Recently Maiti (1968) has published a report of preliminary screening of 202 plants belonging to 162 genera distributed over 64 families wherein many sources of alkaloids, saponins and sterols have been observed. He has not, however, described the relationships of plants having similar chemical compounds.

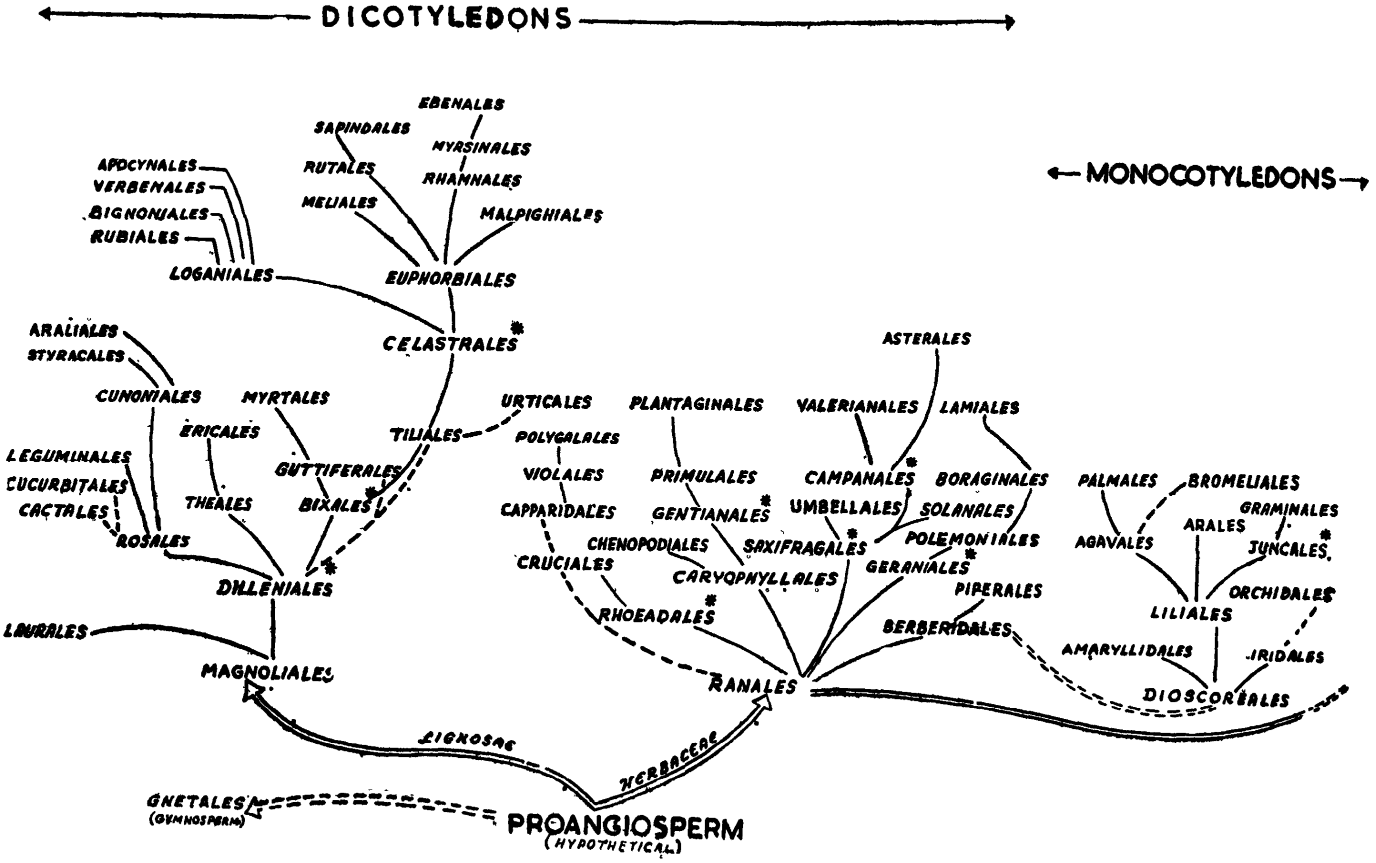
During recent years the steroidal saponins have acquired a new interest for the synthesis of steroidal hormones and wide scale surveys have been undertaken throughout the world. Large number of species of the genera of *Dioscorea, Yucca, Agava, Nolina, Solanum* etc. are being investigated for this purpose. Hence it would be quite helpful to analyse the problem from the point of view of taxonomy, as from such a study it may be possible to predict the sources and even the nature of saponins that may be found in them. The main object of the present study is therefore, to find out the phylogenetic relationship in Angiosperms, in relation to the distribution of saponins in them.

Saponins are a well known group of glycosides, widely distributed in the higher plants. These compounds have been isolated from about 300 or more genera and large number of species. From their structural characters, saponins can be divided into two groups: (i) steroidal saponins *i.e.*, the saponins containing a steroidal ring system in their genins and (ii) triterpenoid saponins *i.e.*, the saponins containing triterpenes in their genins. From their structural point also, these two groups show their individuality with regard to their occurrence in distinctly different groups of plants. The steroidal saponins, are present in both the groups of Angiosperms and their distribution suggests that these compounds were produced in the advanced evolutionary process. They are found in (1) Corolliferae of Monocotyledons (*Hutchinson*, 1959) and (2) in some advanced groups of Dicotyledons. As all the saponin bearing plants show continuity among related plants in the evolutionary diagrams and as also presence of saponins can be detected with certain amount of certainty, all the types of saponins were selected as test compound for tracing the phylogenetic trend in Angiosperms.

A survey was carried out among the saponin-bearing plants in Agiosperms (see list at the end of paper) and were tabulated according to their position in the phylogenetic tree. Though the list is not as exhaustive as it should be, yet some trends can easily be found out. It has been found that saponins do not occur among isolated groups but there is a marked affinity among plants containing similar saponins. It is observed that triterpenoid saponins are present in all the primitive orders of Dicotyledons and are found in a continuous chain in some particular branches in the evolutionary series up to a certain level. The pattern of distribution of saponins indicates that triterpenoid saponins appeared quite early even in the lower vascular plants which may be considered as the ancestors of the present angiosperms and subsequently with the evolution of higher groups of plants and also of their metabolic changes, the saponins either disappeared or modified into other types of compounds. The saponins also became more and more complex with evolution and steroidal saponins can only be found where Angiospermous plants are much more developed.

When an attempt was made by the authors to find according to the systems of classification advanced by Hallier (1912), Bessey (1915) and Hutchinson (1919), it was found that the relationships of different orders of Angiosperms as evidenced by the distribution of saponins in them, is fairly well brought out in the arrangement of the orders proposed by Hutchinson. Even in this system at certain places in the plan of arrangement of the orders the continuity of saponin bearing orders in the series is broken. In such places the arrangement of classification requires some modifications if presence of saponin is considered as an index of affinity. In some cases, however, Hutchinson himself has indicated some probable alternative paths and a few such alternative suggestions appear to be more suitable to keep the continuity of the orders. In other cases some new changes have been suggested. In some orders like Dilleniales, Celastrales, Saxifragales, etc., it was not possible to test whether these orders contain saponins or not. If, however, a proper search is made, there is ground to believe that saponins may be found in them. A modified arrangement of the system of classification of Hutchinson (1959) has been proposed (see Fig.) where saponin containing orders have shown with their probable evolutionary trend. In this modified classification, these orders where precise information regarding occurrence of saponin among their members is wanting, have also been included provisionally, but with asterisk marks. A few advanced families of Dicotyledons belonging to the group Herbaceae, like Solanaceae, Scrophulariaceae, Acanthaceae, etc., however, contain complex saponins which are steroidal in nature. This type of saponins appear to have evolved quite independently from the other steroidal saponins found in Monocotyledons. Probably these saponins are the final form of complex triterpenoid saponins of Dicotyledons. Basing on the morphological characters, the position of Cucurbitales and Cactales had been considered by Hutchinson himself as anomalous, this appears to be true when the distribution pattern of saponins also is considered. He linked them with Passiflorales, but these orders might have arisen from Rosales, a view also supported by Bessey (1912). It is difficult to keep Violales as well as Polygalales in the Lignosae side, but it would be better if Capparidales be linked with Cruciales; then the order of sequence becomes Cruciales-Capparidales-Violales-Polygalales. Hutchinson had grouped together Rutales, Sapindales and Meliales under a group called 'Pinnatae'; these orders might have arisen from Euphorbiales. The position of Urticles ascribed by Hutchinson is not suitable, it is more in common with Tiliales and Malvales.

According to different authors monocotyledons have been regarded as either monophyletic or diphyletic in origin. Hutchinson has considered that monocotyledons are monophyletic in origin showing close relationship with dicotyledons at one point only—the order Ranales. The monocotyledons however, appear to have a diphyletic origin. The saponin-containing groups have evolved through Dioscoreales from Menispermaceae (Berberidales) and the non-saponin groups from a saponin-free suborder of Ranales. From Dioscoreales three distinct branches—Amaryllidales, Iridales and Liliales have evolved; Liliales in their turn have produced several saponin producing orders, like Arales, Agavales,



and Palmales through Agavales. The position ascribed to Bromeliales and Orchidales in Hutchinson's diagram does not appear to be quite suitable. It appears to the authors that Bromeliales might have arisen from Agavales; and Orchidales from Iridales.

It is interesting to note that Gnetales have also saponins. This fact leads us to suppose that this order might have arisen from the "Proangiosperms" in the early evolutionary process.

CONCLUSION

As closely related plants are expected to have similar chemical compounds, the presence of saponin in plants has been analysed from the point of view of taxonomy in order to predict the sources and even the nature of saponins that may be found in related plants. The interrelationships of different saponin-bearing orders and also families have been studied and an attempt has been made to correlate the saponin-bearing orders and families of plants in Hutchinson's system of classification. On the basis of presence of saponins as a criterion of close relationship, some modifications in his plan of arrangement of orders have been suggested. Some such modifications have incidentally supported some of the views of Bessey (1915) with regard to his system of classification. The proposed relationship of Tiliales and Urticales is a case in point. It has been suggested that the Division Corolliferæ of Monocotyledons has evolved from the Menispermaceae (Berberidales) through Dioscoreaceae and, therefore, diphyletic origin of monocotyledons is thought of. It is felt that in any phylogenetic system of classification, in addition to the usual taxonomic characters, the use of such characters like presence of saponins and also other chemical compounds as indices of relationships has to be considered.

REFERENCES

Bessey, C. E. The phylogenetic taxonomy of flowering plants. *Ann. Mo. bot. Gard.* 2 : 109-164, 1915.

Batesmith, E. C. *Plant Biochemistry in Vistas in Botany*, Edited by W. B. Turill. Pergamon Press, London, 1959.

Chatterjee, A. *Rauwolfia alkaloids* in *Progress in the Chemistry of Organic Natural Products.* 10 : 392-422, 1953.

Gibbs, R. D. Comparative chemistry as an aid to the solution of problems in systematic Botany. *Trans. Roy. Soc. Canad,* 74-103, 1945, GIBBS, R. D. Comparative chemistry and phylogeny of flowering plants. *Ibid.* 39 : 74-103, 1945.

——Comparative chemistry and the relationships of some families of dicotyledonous plants. *Proc. Linn. Soc. Lond.* 56 : 1960.

HALLIER, H. Lorigine et le systeme, phyletique des angiospermes, *Arch. Neerl. Sci. Exact. Mat Ser.* 1 : 146-234, 1912.

HEGNAUER, R. The taxonomic significance of alkaloids in *Chemical Plant Taxonomy*. Edited by T. Swain. Academic Press, London, 1963.

HENRY, T. A. *Plant Alkaloids.* Blackiston, Pa., 1949.

HUTCHINSON, J. *The families of flowering plants.* Vols. I & II. Clarendon Press, Oxford, 1959.

MAITI, P. C. Phytochemical screening. *Bull. bot. Surv. India* 10 : 111-122, 1968.

MANSKE, R. H. F. AND H. L. HOLMS. *The Alkaloids.* Academic Press, Inc., New York, 1950.

A LIST OF GENERA CONTAINING SAPONINS

LIGNOSAE (WOODY DICOTYLEDONS)

- Magnoliales
  - Illiciaceae—Illicium
- Laurales
  - Myristicaceae—Myristica
- Rosales
  - Rosaceae—Aruncus, Eriobotrya, Quillaja, Spiraea
- Leguminales
  - Caesalpiniaceae—Bauhinia, Cassia, Caesalpinia, Gleditsia, Gymnocladus, Mezoneuron
  - Mimosaceae—Acacia, Albizzia, Entada, Pithecellobium
  - Papilionaceae—Abrus, Adinobotrys, Aspalanthus, Astragalus, Cicer, Dalbergia, Derris, Erythrina, Galega, Glycine, Glycyrrhiza, Medicago, Milletia, Ononis, Oxylobium, Phaseolus, Piscidia, Pongamia, Psoralea, Sesbania
- Cunoniales
  - Hydrangeaceae—Hydrangea
- Styracales
  - Styracaceae—Styrax
- Araliales
  - Araliaceae—Aralia, Arthrophyllum, Fatsia, Hedera, Heptapleurum, Panax, Polyscias, Trevesia
  - Caprifoliaceae—Diervilla, Lonicera, Sambucus, Symphoricarpos
- Urticales
  - Moraceae—Ficus
  - Urticaceae—Urtica
- Capparidales
  - Capparidaceae—Capparis, Crataeva
- Violales
  - Violaceae—Viola
- Polygalales
  - Polygonaceae—Monnina, Polygala, Securidaca, Xanthophyllum
- Cucurbitales
  - Cucurbitaceae—Citrullus, Cucumis, Echinocystis, Lagenaria, Luffa, Momordica, Trichosanthes
- Cactales
  - Cactaceae—Cereus
- Tiliales
  - Elaeocarpaceae—Elaeocarpus, Sloanea
- Malpighiales
  - Linaceae—Roucheris
  - Balanitaceae—Balanites
  - Zygophyllaceae—Guaiacum
- Euphorbiales
  - Euphorbiaceae—Cicca, Cleistanthus, Euphorbia, Jatropha, Mercurialis, Mallotus, Manihot, Phyllanthus
- Theales
  - Theaceae—Adinandra, Camellia, Cordonia, Laplacea, Schima, Stuartia, Ternstroemia
  - Saurauiaceae—Saurauia
- Ericales
  - Clethraceae—Clethra
  - Ericaceae—Leucothoe
- Guttiferales
  - Clusiaceae—Calophyllum
- Myrtales
  - Myrtaceae—Eugenia
  - Lecythidaceae—Barringtonia, Lecythis
- Rhamnales
  - Rhamnaceae—Ceanothus, Colletia, Colubrina, Gouania, Helinus, Rhamnus, Zizyphus
  - Vitaceae—Vitis, Leea
- Myrsinales
  - Myrsinaceae—Aegiceras, Ardisia, Embelia, Maesa
- Ebenales
  - Sapotaceae—Achras, Argania, Bassia, Dumoria, Lucuma, Mimusops, Omphalocarpum, Palaquium, Payena Sideroxylon
- Rutales
  - Rutaceae—Choisya, Dictamnus, Limonia, Xanthoxylum
  - Simaroubaceae—Ailanthus
  - Burseraceae—Commiphora
- Meliales
  - Meliaceae—Walsura
- Sapindales
  - Melianthaceae—Melianthus
  - Sapindaceae—Blighia, Cardiospermum, Cupania, Deinbollia, Dodonaea, Elattostachys, Erioglossum, Euphoria, Filicium, Guioa, Haplocoelum, Harpullia, Jagera, Lepidopetalum, Lepisanthes, Magonia, Nephelium, Paullinia, Otophora, Sapindus, Sarcopteryx, Schleichera, Serjania, Trigonachras, Valenzuelia
  - Hippocastanaceae—Aesculus
- Loganiales
  - Oleaceae—Chionanthus, Jasminum, Ligustrum, Phillyrea
- Apocynales
  - Apocynaceae—Nerium, Strophanthus
  - Asclepiadaceae—Cynanchum, Decalepis,. Dregrea, Hemidesmus, Marsdenia, Xysmalobium
- Rubiales
  - Rubiaceae—Cephaelis, Cinchona, Chiococca, Gardenia, Leptodermis, Mitchella, Morinda, Mussaenda, Randia, Rubia
- Bignoniales
  - Bignoniaceae—Bignonia, Jacaranda, Oroxylum
- Verbenales
  - Verbenaceae—Clerodendrum, Duranta, Gmelina, Lippia.

HERBACEAE (HERBACEOUS DICOTYLEDONS)

- Ranales
  - Helleboraceae—Helleborus, Trollius
  - Ranunculaceae—Adonis, Anemone, Clematis, Hepatica, Nigella, Ranunculus
  - Podophyllaceae—Caulophyllum, Leontice
- Berberidales
  - Lardizabalaceae—Holboellia
  - Menispermaceae—Albertisia, Arcangelisia, Cissampelos, Coscinium, Diploclisia, Limacia, Stephania, Tiliacora
- Piperales
  - Piperaceae—Piper
- Cruciales
  - Cruciferae—Capsella
- Caryophyllales
  - Caryophyllaceae—Agrostemma, Arenaria, Dianthus, Gypsophila, Herniaria, Lychnis, Melandrium, Saponaria, Silene
  - Ficoidaceae—Trianthema
  - Portulacaceae—Portulaca
- Chenopodiales
  - Phytolaccaceae—Phytolacca
  - Chenopodiaceae—Atriplex, Beta, Chenopodium, Eurotia, Kochia, Spinacia
  - Amaranthaceae—Amaranthus
- Primulales
  - Primulaceae—Anagallis, Androsace, Cyclamen, Lysimachia, Primula, Samelus, Soldanella, Trientalis

- Plantaginales
  - Plantaginaceae—Plantago
- Umbellales
  - Umbelliferae—Dupleurum, Centella, Eryngium, Pimpinella, Sanicula
- Valerianales
  - Dipsacaceae—Succisa
- Asterales
  - Compositae—Aster, Baccharis, Bellis, Calendula, Centipeda, Dimorphotheca, Grindelia, Mikania, Mutisia, Olearia, Oldenburgia, Sanicula, Senecio, Solidago, Teraxacum, Tussilago, Xanthisma, Zinnia
- Solanales
  - Solanaceae—Acnistus, Cestrum, Fabiana, Lycopersicon, Scopolia, Solanum
- Polemoniales
  - Polemoniaceae—Cobaea, Polemonium
- Boraginales
  - Boraginaceae—Pulmonaria
- Lamiales
  - Labiatae—Collinsonia, Galeopsis, Lamium, Orthosiphon, Salvia, Thymus

CALYCIFERAE (MONOCOTYLEDONS)

- Bromeliales
  - Bromeliaceae—Bechtia

COROLLIFERAE (MONOCOTYLEDONS)

- Liliales
  - Liliaceae—Aletris, Aloe, Chamaelirium, Chlorogalum, Convallasia, Erythronium, Lilium, Metanarthecium, Muscari, Rohdea, Smilacina
  - Trilliaceae—Medeola, Paris, Trillium
  - Smilacaceae—Smilax
  - Ruscaceae—Ruscus
- Arales
  - Araceae—Arisaema, Arisarum, Arun, Colocasia
- Amaryllidales
  - Amaryllidaceae—Agapanthus, Allium, Manfreda
- Iridales
  - Iridaceae—Crocus
- Dioscoreales
  - Dioscoreaceae—Dioscorea
- Agavales
  - Agavaceae—Agave, Furcraea, Nolina, Samuela, Yucca
- Palmales
  - Palmae—Phoenix
- Orchidales
  - Orchidaceae—Cypripedium, Luisia

GIUAUFLORAE (MONOCOTYLEDONS)

- Graminales
  - Gramineae—Agropyron

GYMNOSPERMS

- Gnetales
  - Gnetaceae—Ephedra, Gnetum